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Rocket and Laboratory Studies in Astronomy

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Status Report for the Period
September 1, 1995 - August 31, 1996

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I. INTRODUCTION

This report covers the period from September 1, 1995 to August 31, 1996. During the reporting period we launched one rocket experiment, the Faint Object Telescope, from Woomera, Australia for far-ultraviolet long-slit spectroscopy of the core of 30 Doradus. This experiment was unsuccessful for reasons described below. We have continued our laboratory studies of the ultraviolet performance of charge-coupled-detector (CCD) arrays and are including a UV-sensitive CCD in a new payload that was integrated for flight during the current period. The objective of the experiment is the ultraviolet imaging of Jupiter and we are scheduled to launch the payload, 36.115UG, in October 1996. We have also begun to refurbish the Faint Object Telescope for a campaign to study comet Hale-Bopp in April 1997.

II. ROCKET EXPERIMENTS

36.132 UG

This experiment was to be a reflight of 36.109 UG, from Woomera, Australia, to obtain long-slit (100" x 12") far-ultraviolet (FUV) spectra in the bandpass 912 - 1300 Å, with a resolution of ~10 Å, of the stars in and around R136. This complex is located in the 30 Doradus region in the Large Magellanic Cloud, one of the largest giant H II regions in the local group of galaxies. The core of this nebula, R136, was once thought to be a supermassive star but has recently been shown by the newly refurbished HST to be composed of ~3000 hot stars. This cluster is now thought to have formed in a burst of star formation activity some 3.2 Myr ago. The proximity of such a large starburst region to our own galaxy provides a unique setting to view up close the structure of a starburst core and an opportunity to link its properties to starburst regions in more distant galaxies. The observations were intended to investigate the hottest stellar populations of the starburst region, the nebular extinction and provide a serendipitous search for nebular emission.

The payload was launched from Woomera, Australia, on October 29, 1995. Two anomalies occurred in flight, either of which was sufficient to prevent a successful mission. The uplink radio signal was overwhelmed by an unknown ground transmitter, frustrating our ability to track the target and to command the high voltage. In addition, the high voltage (HV) for the detector failed to reach the operational level of –3400 V showing instead a noisy voltage that gradually increased from ~ –1600 to –2400 V. We suspected a coronal level pressure was causing arcing in the HV harness located in the passively evacuated electronics section because the pressure measured in the optical section was very low (~ 10^{-6} Torr). Post-flight vacuum tests at JHU successfully reproduced the anomalous HV levels at pressures ranging between 1–2 Torr (pressures equivalent to an altitude of 40–50 km; our apogee was 300 km). We found a good correlation between HV and pressure and we infer the pressure in the electronics section never fell below 1 Torr during the flight. This pressure is over 100 times higher than encountered in previous flights and we suspect outgassing is not the problem. We now favor the hypothesis of a steady-state leak through a series of small holes in our aft bulkhead where we connect to the WFF support sections. To our knowledge the only source on board that has enough gas to sustain a steady-state leak for the duration of the flight is the ACS N_2 high pressure tank, but there is insufficient evidence to support this conclusion. These anomalies are still being investigated by WFF personnel. In future flights of this payload, we will redesign the HV harness so as to sustain operation at coronal pressures throughout a flight and amend our WFF vacuum tests to include the coronal pressure regime.

36.115 UG

We have completed the development of a Fine Pointed Telescope (FPT) payload to image Jupiter in the spectral region from 1200 to 1650 Å. The goal is to obtain simultaneous images of the spectrally separated molecular and atomic hydrogen emission from Jupiter's aurora with better than 1 arc-second spatial resolution. To achieve the objective, an aberration corrected dispersing prism, CCD detector, and image motion compensation servo are incorporated into a new 16 inch f/24 Cassegrain telescope payload. The image motion compensation servo is designed to compensate rocket jitter on the order of 0.25 arc-seconds at a frequency of 100 Hz. This precision is achieved with two piezoelectric motors that can tip and tilt the telescope secondary mirror to null an error signal produced by a quad-cell star tracker in the experiment. The spectrograph dispersing prism, made of LiF for high UV transmission, has curved surfaces to correct the aberrations ordinarily incurred by a converging beam through a prism. Two types of CCD detectors have been evaluated for sensitivity in the UV (see below). We have chosen to use a thinned, backside-illuminated device from Scientific Imaging Technologies because of its large active area and high quantum efficiency. The flight dewar is a Joule-Thomson cryostat that will cool the CCD to 160 K. Integration at Wallops was completed in August 1996. Due to range constraints, launch from White Sands is anticipated for October 20, 1996.

36.156 UG

Comet C/1995 O1 (Hale-Bopp) was discovered in July 1995 when it was already a 10th magnitude object at a heliocentric distance of ~7 AU. Conservative extrapolations suggest that Hale-Bopp will be a bright naked-eye object (visual magnitude of −1) when it approaches perihelion in April 1997. Hale-Bopp is not a "new" comet and so is not likely to fade as it approaches perihelion. Recent observations (March–July 1996) appear to confirm this hypothesis. The apparent large size of the nucleus (~40 km), derived from *HST* photometry, also seems to be confirmed by the recent detection of cometary volatiles at a heliocentric distance of 4.8 AU from both ultraviolet and radio observations. For comparison, the recent naked-eye comet Hyakutake has a diameter estimated from radar echoes to be less than 3 km in diameter, and was visually bright because of its near (0.11 AU) approach to Earth.

Unfortunately, the viewing geometry for Hale-Bopp during the period around perihelion will be quite poor because of the relatively small solar elongation angles during this time frame (<46° between March 1, 1997 and April 25, 1997). In the past, we successfully launched time-critical experiments for four different comets (Kohoutek in 1974, West in 1976, Halley in 1986, and Austin in 1990), all at solar elongation angles less than 30°, utilizing the unique capability of sounding rockets to utilize the Earth limb to occult the sun. Comets represent an ideal class of extended emission-line object, the spatial distribution of the emitting species providing information about densities, excitation mechanisms, collisional and radiation entrapment effects and outflow dynamics. Long-slit ultraviolet imaging spectroscopy is a powerful technique for studying the physics and chemistry of the cometary atmosphere.

We had originally intended to re-fly our new rocket telescope, capable of 1″ stability, by means of its internal image motion compensation system. However, the first flight of this payload, 36.115 UG, scheduled for this summer, has been delayed by a few months, which together with the short time available for payload preparation, has led us to switch to a reflight of our Faint Object Telescope payload, last flown in Australia in October 1995. Nevertheless, we expect to achieve a factor of ten improvement in spatial resolution over the results obtained with this same payload on comets Halley and Austin where manual control of the pointing resulted in significant jitter. The improvement in spatial resolution will be obtained from a combination of factors: Hale-Bopp will be sufficiently bright for the ACS startracker to lock and track on it so that the jitter can be removed in the data processing using the ACS error signals; and we will be using a holographically ruled grating and a new delay-line MCP detector that will improve the resolution along the slit of the spectrograph. In addition, the detector will be in a sealed enclosure with a CaF_2 window to filter out the very strong cometary Lyman-α emission at 1216 Å.

We intend to address a number of outstanding problems in cometary physics and chemistry, primarily those concerned with the origin of CO and sulfur in the coma. In particular, we will address the interesting result obtained in 1986 during the *Giotto* flyby of comet Halley that the abundance of CO coming directly from the nucleus is only about one-third of the total in the coma, while the remainder comes from a distributed source peaked ~10,000 km from the nucleus.

We plan to use the backup mirror of our existing telescope with a coating of Al/MgF_2 tuned to a peak in reflectivity near 1400 – 1500 Å. High spatial resolution will be achieved with a holographically ruled (1020 l mm^{-1}), astigmatism corrected grating, made by American Holographic, that we possess. The detector and grating will be housed in a spectrometer vacuum housing sealed with a CaF_2 window. The spectrometer housing is identical to one we have flown in the past and we are expecting delivery of a new housing by the end of October.

Mechanical and electrical interfaces to the detector have been defined and work is proceeding with the detector procurement. WFF has recommended that the old 36.132UG telemetry be rebuilt. Our goal with the detector electrical interface is to make it identical to the current (parallel) primary science data channel. We will modify the redundant data channel to include an analog channel of the spectral histogram as this is a direct output of the delay-line detector.

III. DETECTOR DEVELOPMENT

During the past few years we have shifted our emphasis in detector development from simplified readout schemes for microchannel plate (MCP) array detectors to the use of emerging large format CCD technology for ultraviolet applications. Such devices promise the ability to achieve higher resolution (either spectral or spatial) than is readily obtainable with MCP arrays, although their application is limited to experiments that do not require photon counting or solar-blind ultraviolet response. In the future, we intend to make direct comparisons between ultraviolet sensitive CCDs and MCP-based detectors for low level spectroscopy at wavelengths below 1200 Å.

IV. DATA ANALYSIS

In parallel with the development of the Jupiter imaging payload, Mr. Morrissey and Dr. Feldman have been analyzing images of Jovian aurora obtained with the Hubble Space Telescope simultaneously with HUT spectroscopy during the Astro-2 mission on March 9, 1995. The results of this analysis have been accepted for publication in the Astrophysical Journal and will be published in early 1997.

V. PERSONNEL

During this period, Mel E. Martinez received his Ph.D. His dissertation was entitled "Lyman-α and Lyman-β in the Night Airglow Using the Faint Object Telescope and the Hopkins Ultraviolet Telescope." Dr. Martinez is currently working with the FUSE project at Johns Hopkins University.

PAPERS SUBMITTED

P.F. Morrissey, P.D. Feldman, J.T. Clarke, B.C. Wolven, D.F. Strobel, S.T. Durrance, and J.T. Trauger, "Simultaneous Spectroscopy and Imaging of the Jovian Aurora with the Hopkins Ultraviolet Telescope and the Hubble Space Telescope," *Astrophysical Journal*, February 1997, in press.